Discussion Flows: An Interactive Visualization for Analyzing Engagement in Multi-Party Meetings

Tao Wang[1], Mandy Keck[2], Zana Vosough[3]

[1]SAP Innovation Center, Newport Beach, USA
[2]University of Applied Sciences Upper Austria, Hagenberg, Austria
[3]Independent Researcher, San Francisco, USA

Abstract

Engagement in multi-party meetings is a key indicator of outcome. Poor attendee involvement can hinder progress and hurt team cohesion. Thus, there is a strong motivation for organizations to better understand what happens in meetings and improve upon their experience. However, analyzing multi-party meetings is a challenging task, as one needs to consider both verbal exchanges and meeting dynamics among speakers. There is currently a lack of support on these unique tasks. In this paper, we present a new visual approach to help analyze multi-party meetings in industry settings: Discussion Flows, a multi-level interactive visualization tool. Its glyph-based overview allows effortless comparison of overall interactions among different meetings, whereas the individual meeting view uses flow diagrams to convey the relative participation of different speakers throughout the meeting agenda in different levels of details. We demonstrate our approach with meeting recordings from an open source dialogue corpora and use them as the benchmark dataset.

CCS Concepts

• ***Human-centered computing*** → ***Information visualization;*** *Visualization techniques; Interactive systems and tools;*

1. Introduction

Effective meetings are the key to an organization's success. As a medium for communication and collaboration, people engage with each other in meetings to develop ideas, share information, and form action plans [ALWR15]. In today's highly collaborative workplace, time spent on meetings has become a significant investment. Research shows that average employees spend six hours in meetings per week and managers spend as many as 23 hours [RSK07]. Though organizations understand that meetings are a strategic resource and seek out ways to get the most from them, 71% in a survey of managers considered their meetings unproductive [PHE17]. In particular, the level of engagement during meetings bares notable implications to the cohesion within a team. When the engagement is low, people report lower perceived meeting effectiveness [LRWB09] and diminished decision quality [YCA15]. There is a strong motivation for organizations to better understand what happens in meetings and improve upon.

Yet, there is very little support for meeting organizers to carry post-analysis of meeting engagement. For the purpose of knowledge management, many teams have chosen to record their meetings via conference room technologies in audio or video format. Online meeting systems, whose usage has become widespread due to the COVID-19 pandemic, make recording meetings as easy as clicking on a button. While capturing meeting discussions is no longer a barrier, unpacking interactions and surfacing insights remain a challenge. Conversation is inherently a social process [Ken90]. The words exchanged in a meeting are only part of the story. Standard audio or video players offer little beyond basic replay controls. The advancement of AI technologies, such as Natural Language Processing, can help transcribe and summarize the textual content, but they are less effective in recognizing the intricate social undertone embedded in meetings. In multi-party discussions, which are common in meetings, the group dynamic may easily change to respond to different attendee composition and behaviors [Tan91]. In order to fully understand the engagement in a meeting, it is necessary for users to utilize tools that bring their attention to social cues that might be easy to miss, such as awkward silence or turn-taking behaviors [ST08].

In this paper, we introduce *Discussion Flows*[†], a novel visualization approach that assists users in exploring salient engagement patterns based on typical transcripts of, in-person or online, multi-party meetings (see Figure 1). We demonstrate our solution with an open source corpora collected from real world meetings that feature spoken-language and topic-oriented discussions. After a brief review of the related work, we report on our design process including a user-centered requirement gathering process, tasks selection, and our prototype designs. We conclude the paper with a discussion of the challenges faced and proposals for the future work.

[†] https://discussionflows.github.io/

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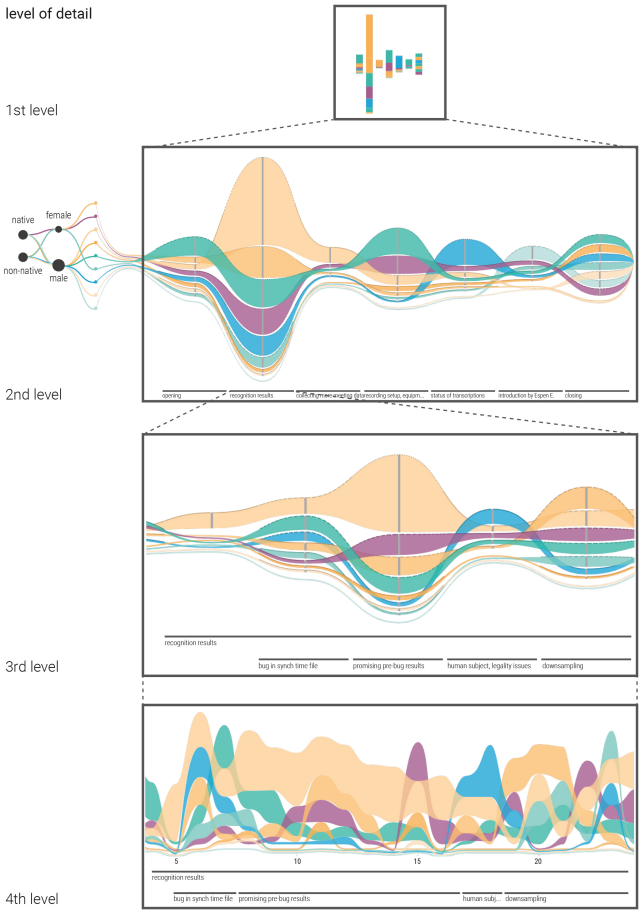

Figure 1: *Discussion Flows visualizing the engagement of 9 participants in a meeting with 7 agenda topics in four levels of detail.*

2. Related Work

Conversations can take many forms. They differ in the application domains but share the common goal of communication. Visualization has been used as an intuitive and effective way of revealing patterns and supporting comprehensions in these conversations. Based on the nature of the data, they fall into the following groups.

Text-based: A large body of work focuses on text-based communications online, whose structures are often obfuscated by the vast volume of information. Visualizations help users perceive these patterns, such as analyzing relationships in emails [VN03], team collaboration patterns [FZC*18], or group dynamics in online forums [Don02, DKV99]. Some research tries to visualize large volume of information in limited space, such as chat history [TC06], or help users distill key information from large data, such as recognizing main themes of emails over time [VGD06, HLH11].

Speech-based: Speech-based data is transcribed from spoken conversations. It differs from text-based data in its informality and loose structures. It is also uniquely susceptible to social interactions among speakers. Such properties present challenges but also exciting design opportunities. El-Assady et al. introduces ConToVi, a visual analytics approach to analyze speaker interactions and behavior patterns over time in political science themed multi-party conversations [EAGA*16]. Shi et al. designed MeetingVis that visualizes five primary narrative elements from meetings to help users recall meeting context and content [SBB*18]. Furthermore, researchers are also interested in representing non-verbal or emotional content of the conversation such as gaze, speech rate, or prosody without considering the semantic content of the text [SGN*07]. For example, in Conversation Clock turn-taking actions and speakers' volume are captured in real time to visualize a history of interactions among co-located meeting attendees [BK07]. However, capturing these data can be expensive as it requires installing many apparatuses in the environment [NRZR06].

Discussion Flows differs from prior work in its main goal of helping users discover implicit social cues and assess meeting engagement. It experiments a multi-level approach to support various objectives during user explorations, from investigating patterns at the topic level to unpacking interactions at ephemeral moments.

3. Design Process

Prompted by Munzner's four-level nested model for designing visualization systems [Mun09], we underwent the following steps.

3.1. Domain Situation

We started with a user-centered design process [AMKP*04] to ensure that our design goals were grounded on realistic use cases. We conducted ten semi-structured interviews with participants recruited from our industry partner SAP, a large enterprise software company. The participants are from a wide range of roles and they attend group meetings frequently. Interviews lasted between 15 to 30 minutes. The participants were asked to discuss around two probing questions: (1) what would they want to know if they miss a team meeting? (2) what would they want to share about a meeting if asked by someone else who has missed it? We learned that:

- The inquiry is driven by agenda: participants are interested to discussions related to their responsibilities, such as the project they work on. However, the definition of relevance is broad. Seemingly irrelevant projects might be useful if they share similar work items. Their experience with one meeting is often influenced by past meetings from the same serial.
- Context is important when interpreting decisions: participants want to know how a decision was reached, such as who proposed the solution or how much deliberation happened; then they assess the quality of the decision accordingly.
- Long-term engagement patterns are informative for managing a group: participants with managing responsibilities also emphasized the importance of being able to understand the participation of all group members across multiple meetings.

3.2. Visualization Tasks and Data Structure

The interviews helped us identify users with managing roles, e.g., team managers, technical leads, as the target users, because their responsibilities require them to pay attention to engagement from both a productivity and a team building aspects. Along with the need of maintaining the agenda and context, two critical elements emerged from the interviews, we defined the following *tasks*:

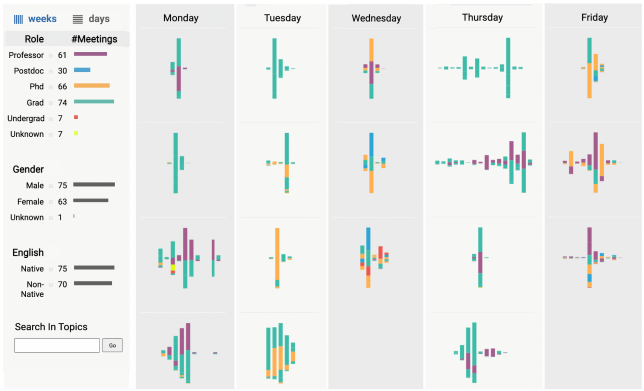

Figure 2: *Discussion Flows overview page visualizing ICSI dataset. The current weekly view shows the involvement of the participants into different meeting agendas based on their roles.*

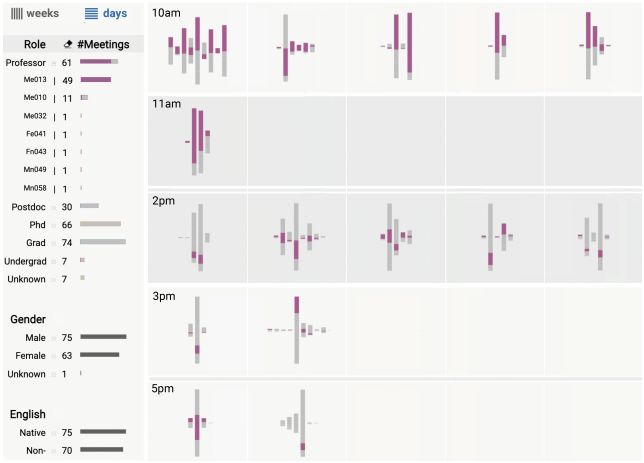

Figure 3: *A time view of the same dataset shown in Figure 2 when the first professor (ME013) in the list is selected to analyze his discussion contributions during different time of the day. Hours without meetings are minimized to assist the comparison.*

- **T1:** Users should be able to compare and contrast participant engagement in multiple meetings based on their desired criteria.
- **T2:** Users should be able to analyze meeting structures and speaking behavior in detail, such as the turn-take patterns, presentation formats, or interruptions.
- **T3:** The transition between levels should be logical and intuitive.

After specifying the problem domain and defining the data input, we derived a domain-independent vocabulary for the users tasks and data. We chose to develop our prototype using *ICSI's Meeting Recorder Dialog Act (MRDA) Corpus* [SDB*04]. It was collected at the International Computer Science Institute in Berkeley in early 2000's. It consists of 75 work meetings on several projects. Most run just under an hour and involve at least six speakers. The dataset is released with rich annotations, including word-level orthographic transcriptions, topic assignments, and detailed speaker information.

3.3. The Discussion Flows Visualization

Discussion Flows reconstructs the engagement of a meeting by conveying both participants' discussion contributions and speaking behaviors. We developed it as a web-based prototype using HTML5 and JavaScript. To visualize a large number of items in a limited space, we followed Shneiderman's mantra [Shn03] and designed four views to meet user needs at different steps of analysis.

Glyph-based view (Level 1): At the top level, *Discussion Flows* provides an overview of all meetings. Users can choose either a *week view* where meetings are sorted into different columns representing days of a week (Figure 2) or a *time view* where meetings from the same week are sorted into rows representing time slots (Figure 3). Time slots without meetings are minimized to save interface estate. We chose a glyph-based approach, which represents each meeting as a small independent visual element. A main strength of glyphs is that they allow the identification of patterns involving several dimensions and they can be placed in different layout strategies [BKC*13, War08]. Each glyph contains several color-coded stacked bars. Each bar represents an item in the meeting agenda and they are placed in the same order as they were discussed in the meeting from left to right. Each colored segment in these stacked bars represent one speaker and the height corresponds to the duration of that person's involvement in the agenda. In Figure 2, one can easily discern meetings that had many different agenda items (i.e., number of bars), the main discussions (i.e., relative height of bars), and the level of involvement of the team in a discussion (i.e., number of colored segments within a bar).

The colors used in the glyphs denote additional attributes about speakers. The left side of the interface provides various filters that help analyze meetings based on the speakers' role, gender, or native language. Each category employs a different color theme. When selected, all glyphs would be updated to the corresponding colors to contrast the differences among options within this category. The speaker role is the default color theme. If a single option within a category is selected as filter, we highlight the contributions from applicable participants by greying out other's contributions. Users can go further to select a single individual to compare this person's contributions in different meetings. In addition, we offer a "Search in Topics" feature to help locate all topics containing the keyword.

These glyphs and filters enable users to conduct focused meeting comparisons **(T1)**. Figure 2 shows an example of the overview in the *week view*. The filter panel includes a summary of the number of meetings in each category. In this example, roles are defined as Professor, Postdoc, PhD, Grad, Undergrad, or Unknown. Figure 3 shows the same dataset but organized in the *time view*. A filter is applied to show contributions from the first professor in the list. The visualization makes it immediately obvious that the selected professor plays a more active role in morning meetings **(T2)**.

Flow diagrams (Level 2, 3, & 4): To assist further analysis of a particular meeting, *Discussion Flows* offers three more levels of details that can be accessed by selecting the target of interest or zooming (**T3**). They provide more information about a meeting by visualizing how participants with different roles and attributes behave at different parts of the meeting agenda. We adopted flow diagrams [Tuf85] to convey a participant's engagement from one

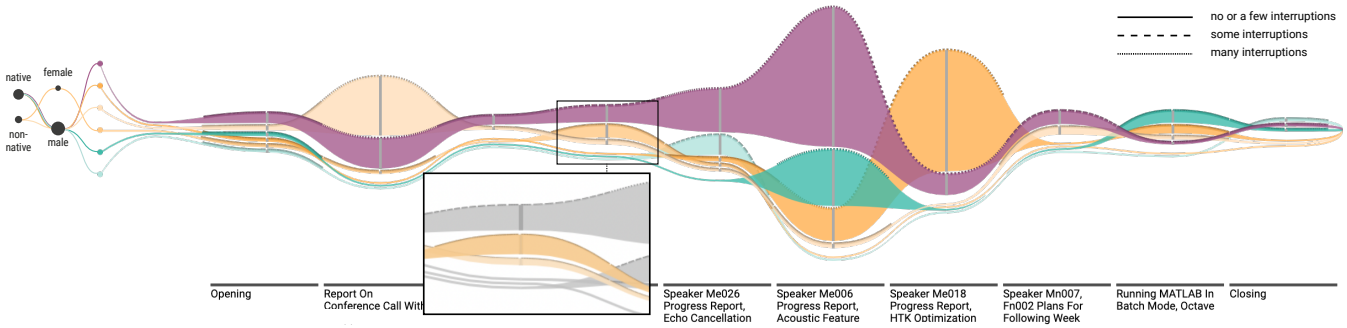

Figure 4: *An example of Discussion Flows level 2 view visualizing the involvement of 6 participants into 10 agenda topics over time. In the overlaid rectangle, one can see the interruption patterns of non-native speakers after applying filters.*

agenda to another. Similar to the glyph design, the vertical axis depicts the duration of time spent on one agenda and the horizontal axis represents the order in which the agendas were discussed. To help trace a speaker, the flows of speakers who do not contribute to an agenda are still drawn, but passing below the agenda bar. Agenda descriptions were printed under the corresponding bars.

Flow diagrams allow using more visual attributes to convey additional engagement information. The current prototype conveys interruptions. We designed three types of lines to a flow's top edge to indicate how often a speaker is interrupted over an agenda (see Figure 4). We approximate the level of interruption based on the number of utterances. A solid line means no or little interruptions, a dashed line means some interruptions, and a dotted line means many interruptions. We also introduced different shades of color in this view. The flow diagram inherits the same color theme from the overview page so that users can maintain a consistent visual impression of the engagement depicted, especially necessary if they follow through from filtered results. For multiple participants with the same role, we take the role color as the base color and produce different shades according to other distinguishing attributes. In the current implementation, we use speaker age for this calculation. Finally, a small Parallel Coordinate [ID90], shown on the left side of the flows is designed to augment participants with additional attributes. They also serve as filter controls. Users can select an attribute to highlight the corresponding flows.

Figure 4 shows an example of how users could employ these dynamic features to explore engagement in a meeting. One can immediately see that the professor (purple) was the main contributor to most discussions, followed by the PhD students (orange), and finally the Grad (green) students. The PhD and Grad students with more experience (darker color) were more engaged in the discussions. The overlaid rectangle shows an example of filtering by native language. The non-native speakers were not involved in most discussions. They might be there to give a presentation since when they did speak they were not interrupted often. On the other hand, the experienced PhD student (i.e., with the darkest orange) was involved in two large agendas. Their discussions later in the meeting seemed to be more active as there were more interruptions (indicated by the dotted lines).

Level 2 and level 3 flow diagrams differ only at the agenda hierarchy. It is common that a top level agenda has multiple sub items. Therefore, we designated level 2 to show only top level agenda. When users wish to learn more of a discussion, they can zoom in to reveal the current agenda's sub items. (see Figure 1). In contrast, the level 4 flow diagram presents different information. It summarizes participant contributions during a customizable time interval instead of agendas. The level 4 example shown in Figure 1 uses a 60-second interval. With a smaller interval users can observe close-up interactions, such as overlapping of agenda sub items. Filter and highlight features work the same as previous levels.

4. Conclusions and Future Work

Meetings are complex social interactions where the words spoken are only part of the story. By visualizing both verbal exchanges and speaker interactions, *Discussion Flows* helps bring user's attention to a meeting's dynamic that may be easily overlooked otherwise. It is a challenging task to convey social cues visually. For example, interruptions, which is included in our prototype in a basic form, can be constructive during brainstorming but detrimental in other occasions. How do we recognize the signals and present them in a useful way? Additional social cues, such as speaking pace or sub group communication patterns, could contribute to an even richer picture. Subtle social context changes may influence how users behave. How do we anticipate and respond? More research is needed to answer these and more intriguing questions in this space.

Our immediate next step is to conduct iterative usability testing to refine the visualization and interaction designs. We will also plan user studies to understand how *Discussion Flows* would be used in real-life settings and the impact on all involved. We are particularly interested to see if managers may use it to respond to unconscious bias in the workplace, such as women often experience due to gender effects [AL98]. Furthermore, *Discussion Flows* is designed for analyzing meetings with a reasonable length and participated by a medium sized team. The current design is effective within this scope. However, as with any visualization, after surpassing a certain data size, *Discussion Flows* may become ill-suited. At some point the current prototype will reach the limit of number of meetings and participants that it can faithfully represent. In completion of Munzner's nested model's fourth level, we plan to investigate this limit and alternative designs with industry partners. For example, common Focus & Context techniques can be added to the flow visualization similar to Multistream technique [CSWP18], in order to show only a part of interest from a long meeting.

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